1. Inversion of words.

2. Acting as intermediary between the input-output equipment and the serial acoustic memory.

3. Acting as a register for an experimental Williams memory that uses the parallel mode.

The need for inverting numbers or words is brought about as follows. The normal method of writing numbers on paper or putting numbers into the machine via keyboard is to put them in with the most significant digit written first. Thus in writing 38945 we first write the three, then the eight, and so on. However, the machine uses the number with the least significant figure first, for obvious reasons, in addition, subtraction, and so on.

Figure 11 shows in very simplified form, the method by which the shift register does its work. There are 48 flip-flops arranged to form a closed loop. Note that the shift register only shifts in one direction, to the right.

An input operation starts with the clearing of the shift register and the injection of a so-called marker pulse in stage *47*. Its function is to indicate when an operation is completed. After the marker is inserted, the first pulse from the tape or Teletype is entered in position *46*. Soon after this, the loop is shifted by a train of 47 pulses. At the end of this time the marker has advanced one stage to the left, that is, stage *48*, and the first digit is in stage *47*. The second digit is now placed in stage *46*, and this same type of shift takes place again.

This is done 47 times until the marker ends up in stage *46*, the most significant digit in stage *45*, the next most significant digit in stage *44*, and the least significant digit in stage *1*. The fact that the marker is detected by the timing pulse at this time indicates that the word is now in position. The control changes, so that the loop is broken at *A* and *B*, and the next shift train affects only the first 45 stages. This time a 45-pulse train is generated which shifts the word along the bus where it is routed to the memory.

This is the manner in which words are put into the acoustic memory. Getting words out of memory is somewhat similar and proceeds as follows. The marker is again set up in stage *47*, and the number is brought into the shift register via stage *45*. By shifting 45 times, the word is gotten into position with the least significant digit in stage *1*. At a signal from the tape unit that it is ready for information, the digit in *45* is transferred to the tape unit and about 2 microseconds later a shift of 47 steps takes place. This puts the contents of stage *44* in position *45*, and that of stage *45* in position *46*. At the next signal the pulse in *46* is eradicated and that in *45* read out. When the marker finally gets into position *46*, the shift register signals the computer that the operation is over and we are ready to proceed with the next operation.

This completes the general description of the SEAC input-output system with the exception of two units, the read chassis and the synchronizer chassis. However, circuits performing similar functions are described in the paper on auxiliary equipment.

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Input-Output Devices Used With SEAC

JAMES L. PIKE

THE input-output devices that are used with SEAC can be classified rather generally as either low-speed or high-speed equipment. In the low-speed class, the use of Teletype equipment for the baisc keyboard and printer, useful in troubleshooting and program checks, was suggested because of its reliability and its availability.

The principle followed in adapting Teletype to our computer was to avoid any modification to the basic mechanism that would affect its reliability. The code bars were reground and filled in where necessary, to alter the code. Most of the function bars were removed and the few remaining were modified with respect to the code they recognize. A Teletype transmitter-distributor (TD) is used to provide the timing signals to the computer for output printing at the standard Teletype rate.

Work is now in progress on adapting Flexowriter apparatus to the basic input-output functions of a computer. Its operating rate is slightly higher, about 10 characters per second as compared with six for Teletype. The Flexowriter has several advantages in that it may be adapted to perform functions not readily possible with Teletype apparatus. It offers such additional features as upper and lower case letters, 6- or 7- unit code, color change, and tabulating.

The basic difference in the two types of equipment is that Teletype operates sequentially and Flexowriter operates in parallel. The Teletype apparatus is well suited to serial input-output since it includes distributing and collecting apparatus. The Flexowriter, since it is not designed to be operated over long lines, handles the units in each code character simultaneously on separate lines. In many types of computer circuitry, of course, this is a preferable arrangement. The standard Flexowriter system comprises a punched-paper tape reader and a punch built into an electric typewriter as one complete unit. The Teletype machine in use with SEAC for some two and one-half years has proved quite reliable, and it remains to be seen whether Flexowriter equipment will provide similar reliability.

High-Speed Input-Output

As soon as SEAC was put into routine operation, it became evident that a faster system for getting information into and out of the computer would be highly desirable. On many problems the time spent reading punched-paper tape input or printing output on the Teletype printer was more than 95 per cent of the computer time on the problem. This very inefficient use of the computer was remedied by the addition of input-output dumper units. These are magnetic wire recording devices adapted from the mechanism of an office dictating machine, as pictured in Figure 1. This equipment was chosen

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because of the ease of handling the recording medium. The wire is contained on two spools in a closed metal cartridge. This cartridge, shown in Figure 2, carries a pointer traveling over a replaceable paper scale on which the contents of the recorded wire may be labeled. These units can be switched to manual control so that the desired program may be positioned on the wire for input and then switched to computer control so that when the program calls for input from this particular source, it is automatically read in. Typical read-ins require only a few seconds, the speed of the wire being 120 times as fast as when it was recorded from Teletype tape.

The mechanical part of the office-dictating machine may be purchased from the manufacturer unwired and without the associated electronic equipment. One modification required for computer input-output use is a change in the motor capstan size to produce the desired speed, in this case 8 feet per second both forward and reverse. Auxiliary equipment requires a very slow wire speed, about 1 inch per second for transferring information to or from punched tape. For this application a second motor with gear train is mounted in line with the regular motor. The shafts are coupled by means of an overrunning clutch so that either speed may be obtained by simply switching on the appropriate motor.

Another important modification is replacement of the low-quality recording-reproducing head used in the office machine with a higher quality recording head as the Brush *BK. 908*. The mounting requires modification to fit the small space available, but this head produces a much cleaner wave form on the recorded pulses. The cartridges as supplied for office use contain about 1,800 feet of stainless steel wire (3.75 minutes at 8 feet per second). This can be replaced with plated wire, which will allow about twice the pulse packing. Trouble was encountered in attempting to use a cartridge which contains four times as much wire. The difference in the diameters of the spools as the wire reels from the full to the empty spool requires additional guides to keep it in line with the recording head. In spite of the additional guides, there is considerable trouble with misalignment of the wire, and at present use of these cartridges is simply discontinued. The recorder mechanism contains two oiled cork disk clutches operated by solenoids to engage the forward and reverse spool-driving shafts. These solenoids are wired directly into vacuum tube control circuits. The clutches require periodic maintenance to assure their reliable operation.

Considerable trouble has been encountered with the latching system for holding the cartridge into the wire drive mechanism. In many cases the latches became disengaged while the wire was running and allowed the cartridge to jump away from the spool drivers, usually causing the wire to break. Recently the mechanical arrangement for engaging these latches was modified in such a way as to eliminate this trouble. There has still been occasional breakage of wire which is not explained. The plated wire, which gives better recording performance, is somewhat weaker and more brittle mechanically. Considering the great increase in operating efficiency offered by this system, the occasional trouble with broken wire is tolerable. An operator particularly anxious not to lose his time assignment on the computer because of a broken wire may record duplicate programs on separate cartridges and thus have a spare in case of accidental breaking. As in the original operating system of the wire recorder, the engagement of the clutch solenoid closes contacts which start the motor. This gives an acceleration from stand-still to full-speed of the wire in approximately 1 second. Adequate gaps in the recorded program must therefore be provided to allow the wire to reach full operating speed before it enters the information area. This means that it is most efficient to use this device for input or output information requiring few stops and starts between long runs of data.

Auxiliary Memory

A computer such as SEAC has a necessarily limited storage capacity in its internal high-speed memory. With many types of problems this is a serious limitation and requires that information be transmitted out of the computer for storage to be re-entered into the computer later in the program. This means that the speed with which the storage and re-entering can be accomplished is a major factor in the over-all operating speed. A

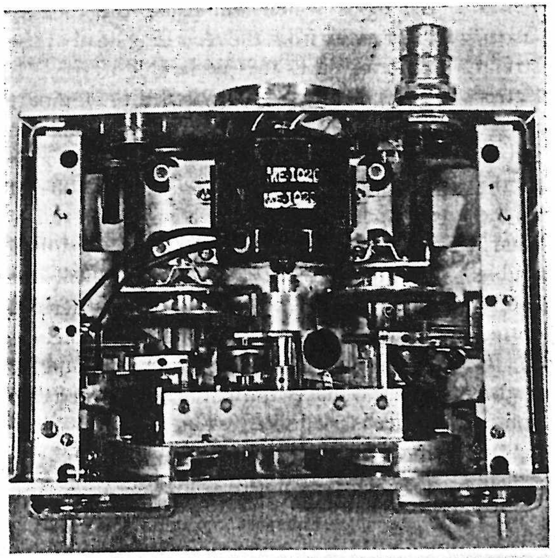

Figure 1 (left). Inside view of input-output dumper wire drive

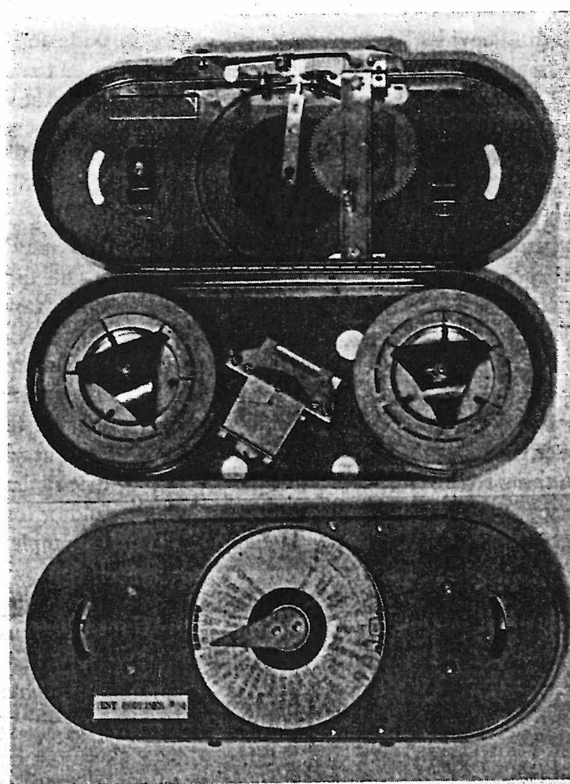

Figure 2 (right). Wire input-output cartridge

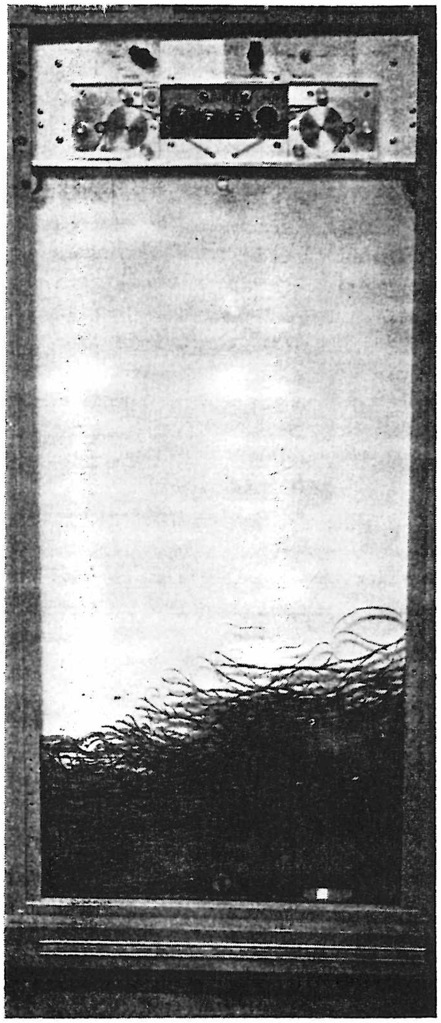

Figure 3 (left). Front view of auxiliary memory tape drive

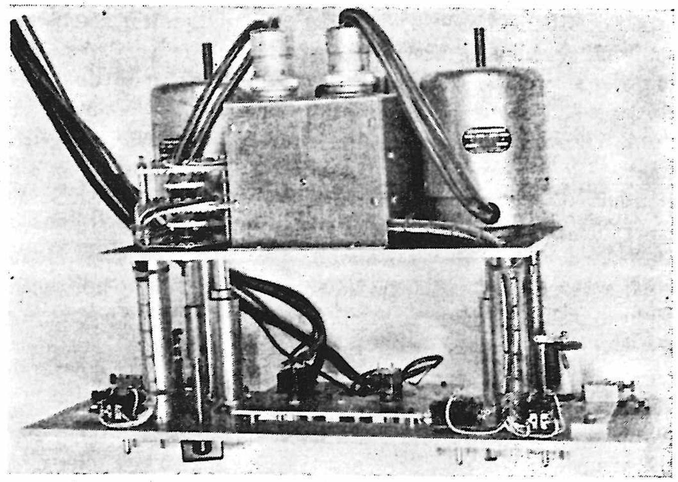

Figure 4 (right). Interior view of auxiliary memory tape drive

common technique is to employ complex and expensive servomechanisms to achieve rapid start, stop, and reversal of the magnetic medium in the magnetic recording device.

In the laboratory a system was devised to solve quickly and economically the problem of overflow memory for the SEAC without the use of servomechanisms. As seen in Figure 3, the device for moving the magnetic tape comprises a capstan turning continuously and a jam roller which may be moved into contact with the capstan by means of a solenoid. The complete tape drive mounts two of these capstan assemblies rotating in opposite directions with the recording heads between. The tape hangs loosely over the capstans and is accelerated to its running speed, typically 5 feet per second, when the jam roller is engaged. The total acceleration time including the solenoid lag is about 5 milliseconds. Individual motors of the dual-speed hysteresis type drive each capstan (Figure 4). They are so mounted as to allow easy replacement by motors of a different speed. The capstans are smooth stainless steel giving very little friction against the loose tape. The jam roller is simply a small ball bearing with a nylon tire pressed on it. The solenoid which moves the jam roller about 0.020-in. is adapted from the coil of a short telephone-type relay.

The four units now in use with SEAC use single-channel bipolar recording with a-c erase on 1/4-inch tape. The use of wider tape and multichannel systems is entirely feasilbe. The tape is stored in a "tank" where it falls in loose random folds from the capstan as shown in Figure 3. This tank is formed by the space between two plates separated by slightly more than the tape width. There is no tendency for the tape to twist parallel to the faces of the tank and therefore no opportunity for snarls to form in the tape. The SEAC units can be operated with up to 3,600 feet of tape in a tank 19 inches wide and 3 feet high. Separate tanks are used to receive the tape from each capstan with the ends of the tape prevented from passing through the mechanism. A single tank may be used with the tape spliced into a continuous loop, but the use of more than about 400 feet of tape in this way may prove difficult.

One difficulty encountered in the use of these tape drives came from the strong tendency of the tape to acquire an electrostatic charge as it passes through the drive mechanism. The charge can be strong enough to cause the tape to stick to the tank near the top until it backs up into the mechanism and is damaged by a sharp fold or fouls the jam roller. This trouble is completely eliminated by the use of a tape now available with an evaporated aluminum film on the back surface. If lucite is used for the tank, this must also be treated to prevent the accumulation of static charges on the surface.

Another problem arises from the presence of flaws in the magnetic tape. Commercially available tape has many small imperfections in the magnetic oxide coating which are quite undetectable in ordinary audio work but cause loss of one or more digits of information in pulse work. With multichannel apparatus there are several systems for avoiding these flaws, but since we are operating a single-channel system, an attempt was made to improve the tape surface mechanically. A technique has been experimentally developed which is quite effective in eliminating flaws from ordinary tape. The recording flaws are caused by nodules of the oxide which project above the normal surface and lift the tape away from the head. They may be removed by passing the tape surface across a properly shaped scraping blade. The physical characteristics of the flaws vary with the manufacturing method, and this technique applies to the product of only one manufacturer, Scotch-type *111*.

A third difficulty arises from the use of plastic tape with this storage method. If a 1,200-foot tape is left immobile in the tank for a day or so, it develops kinks at the loops which will cause the tape to jump away from the recording head at the light pressures it is preferable to use. If the pressure pad is tightened to eliminate this trouble, it causes increased wear on the tapes and heads. A fair compromise may be made by using only about 600 feet of tape in a tank. If a base material of improved resilience is developed, an increase in storage volume will be facilitated. The simplification derived from avoiding the reel inertia problem is paid for by inconvenience in changing tape. This is quite tolerable when the device is used solely as an auxiliary memory.

Auxiliary Equipment to SEAC Input-Output

RUTH C. HAUETER

THE two previous papers have been concerned principally with input-output units and equipment that is actually attached to the SEAC. That which is now described is physically separate from SEAC. This equipment allows the slow work of preparing input programs and data, and of printing the results to be accomplished without using valuable computer time.

The first step in preparing an input cartridge for SEAC is to prepare a punched paper tape from the coder's program. Teletype equipment which has been modified to conform with the SEAC code is used. There are several reasons for having this intermediate step rather than having the program typed directly onto the magnetic wire. First, it makes the wire-recording equipment much simpler, as the wire can be continuously moving. Also, the paper tape can be easily corrected, eliminating the necessity for complicated error-checking circuits. Also, in case of trouble with the wire input to the machine, or in case the wire should be damaged or erased, the paper tape can be read into the computer through the Teletype input or the program re-recorded on wire from the already corrected paper tape.

In SEAC, a hexadecimal code is used for the Teletype characters. This works out well since the actual word length in the mercury tanks is 48 bits. Also, since there are 16 different orders in SEAC, it was a good choice for the instruction word. In the 3-address mode of operation, there are 12 bits to an address, so three characters specify one address. In 4-address operation, where there are 10 bits to an address, one character has to contain part of two addresses. If an octal code had been used, more than one character would have been necessary for the order, and more typing would have to be done. Also, the hexadecimal code requires no change when decimal information is used, since the first 10 characters are identical. As a small convenience, SEAC also uses two of the characters above 10 with the decimal code to provide a decimal point and a space.

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The Inscriber

When the paper tape is correct, its information is transcribed onto magnetic wire for rapid computer input. The unit which does this transfer is called the inscriber. The function of this unit, the use of the cartridge for wire handling, and the use of the cartridge in SEAC, have already been explained briefly.

Whenever there is a considerable delay between input instructions, such as when the machine is halted for a manual operation or when there is a lot of computing between instructions, there must be enough space between the blocks on the wire to allow the wire to stop and then get up to speed again. In SEAC, the complete routine is usually read in before problem computation is started. The spaces between blocks then need only be long enough for SEAC to compute its next read-in instruction. Data are read into the computer several blocks at a time, so again the long space need be inserted only when the wire is allowed to stop. A control on the inscriber allows the operator to change the length of the space at will.

In Figure 1, the block diagram of the inscriber is shown. The punched paper tape reader is a modified Teletype transmitter-distributor. As characters are sensed by the tape reader, the brush passing over four narrow segments on the special commutator provides the recording signals for the wire. Counters are used to halt the tape reader at the end of each block, while the wire continues to move. A high-speed forward motor position is used to read, erase, and test record. By reading is meant audible monitoring of the wire. Used wires can be erased on the unit, and in case bad recording spots are suspected, a test recording of alternating positive and negative pulses can be made, and the wire checked. However, with the wire now in use, this checking does not appear to be necessary.

The inscriber has been in operation for $1^1/_2$ years and gets almost constant use for 16 hours of the day. It is shown in Figure 2. The unit on top is an auxiliary erase unit.

The Outscriber

The unit which performs the reverse function of the inscriber is the outscriber. Beginning with a magnetic wire on which information has been printed by SEAC, it counts the pulses on the wire, stores the information they represent until it has received enough for one character, and then punches this character on a paper tape. During the punching operation, more pulses are coming along and the operation is repeated.

A punched paper tape is produced instead of a printed copy because both card punching and typewriter printing require variable timing cycles for different operations. In the card punch, the card feed time is much longer than the time of punching a column, and in the printer the carriage return time is variable and can be many times longer than the time required to punch a character. By using the punched paper tape it is possible to run the magnetic wire at a constant speed. This reduces difficulties caused by starting and stopping the wire, particularly since the wire drive used has such poor start-and-stop performance. These difficulties are aggravated by the very high gain necessary in the reading amplifier.

Grouping the information which is

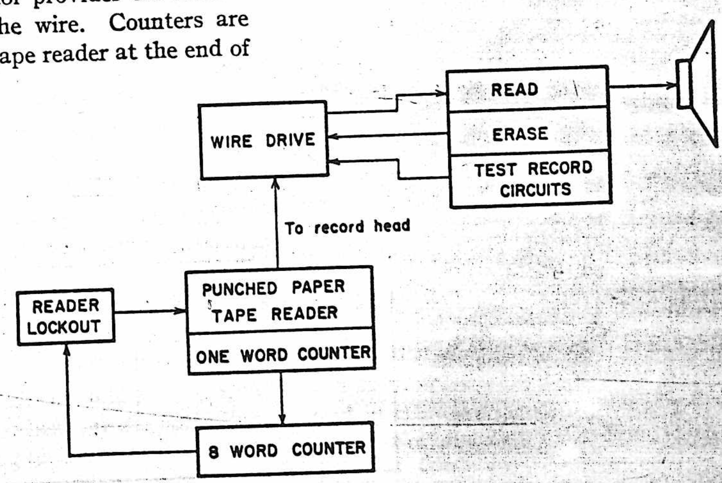
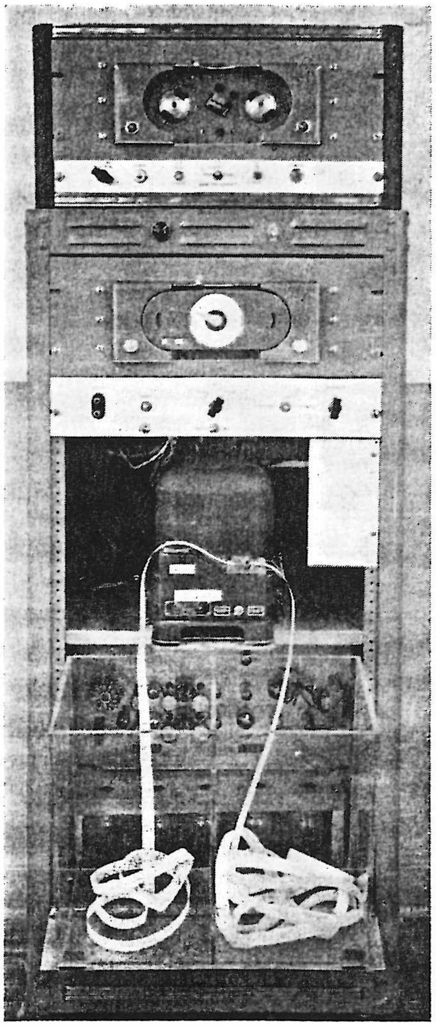


Figure 1. Block diagram of the NBS inscriber



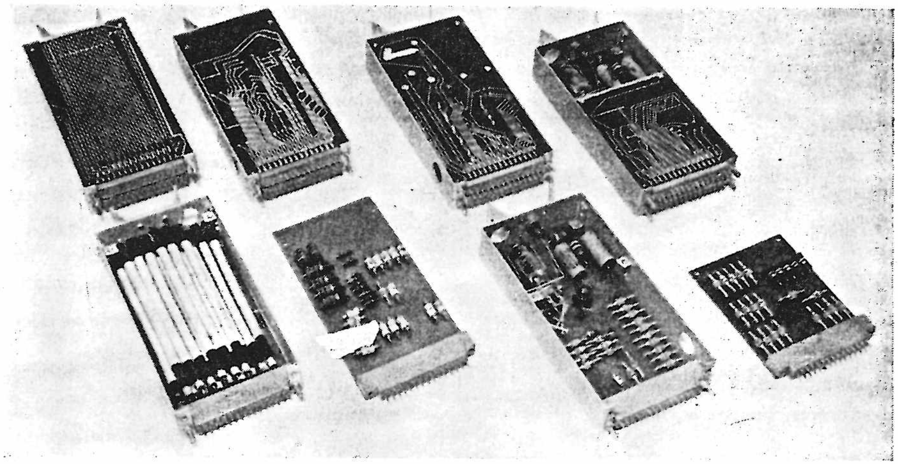


Figure 4. Printed-circuit packages showing exterior and interior construction

Figure 2 (above). The NBS inscriber

coming serially from the wire into characters requires a serial-to-parallel conversion. This means the serial information must be routed into the proper channels. If a character has four bits, four channels are necessary. If a 6-bit character is desired, six channels would be necessary. At the time the outscriber was being planned, a simple modification to SEAC which would enable the alphabet to be used was being considered, and since it involved only a small increase in equipment, it was decided to have either 4- or 6-channel operation available in the outscriber.

As much checking is used as could easily be included without an overbalancing amount of equipment. Since there is already a pulse counter which counts up to one character, a character was decided upon as the most logical unit for checking operation. Also, since the computer prints in blocks, it is easy to sense the gap between blocks and, by examining the counter at this time, obtain an error check. If an error is detected, the wire is halted and an indicator is lit to catch the attention of the operator.

Since the design of a hand-wired 1-stage package for SEAC-type circuitry was almost complete at the time the outscriber was being planned, it was decided to design the outscriber around these packages. This would provide operating experience with the packages before incorporating them into any future computers. SEAC-type circuitry requires synchronous operation based on a 1-megacycle clock. Figure 3 shows several typical packages. A tube and gating package is on the right, next to it is a delay line package, and on the left a package which contains various terminations for the delay lines. Two other computer groups co-operated with National Bureau of Standards (NBS) in the design of these units and they have computers now under construction using similar packages.

A computer is also under construction at NBS, using printed circuit packages

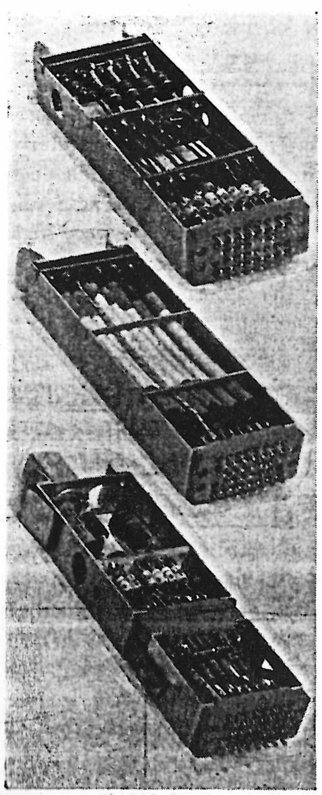
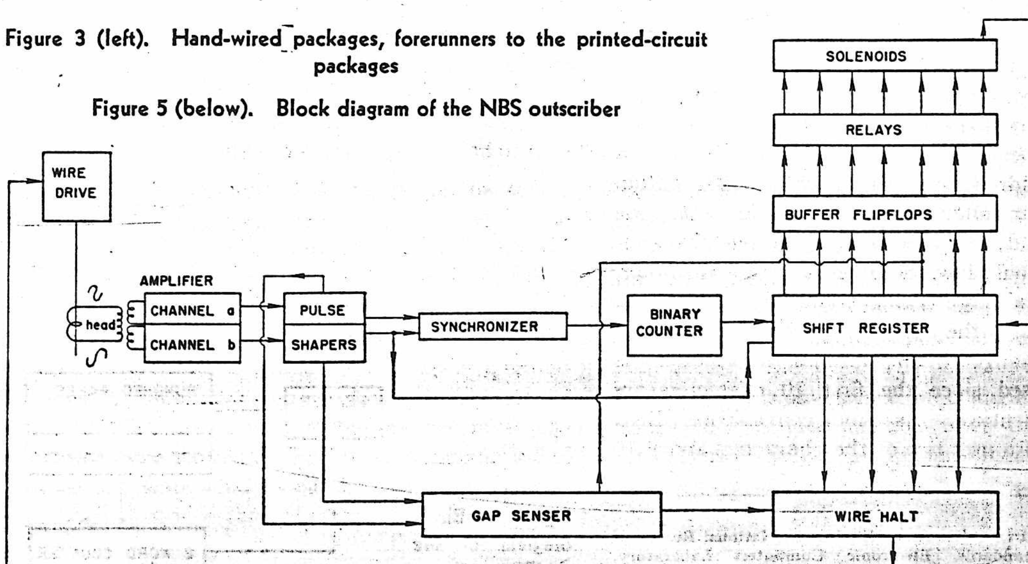


Figure 3 (left). Hand-wired packages, forerunners to the printed-circuit packages

Figure 5 (below). Block diagram of the NBS outscriber



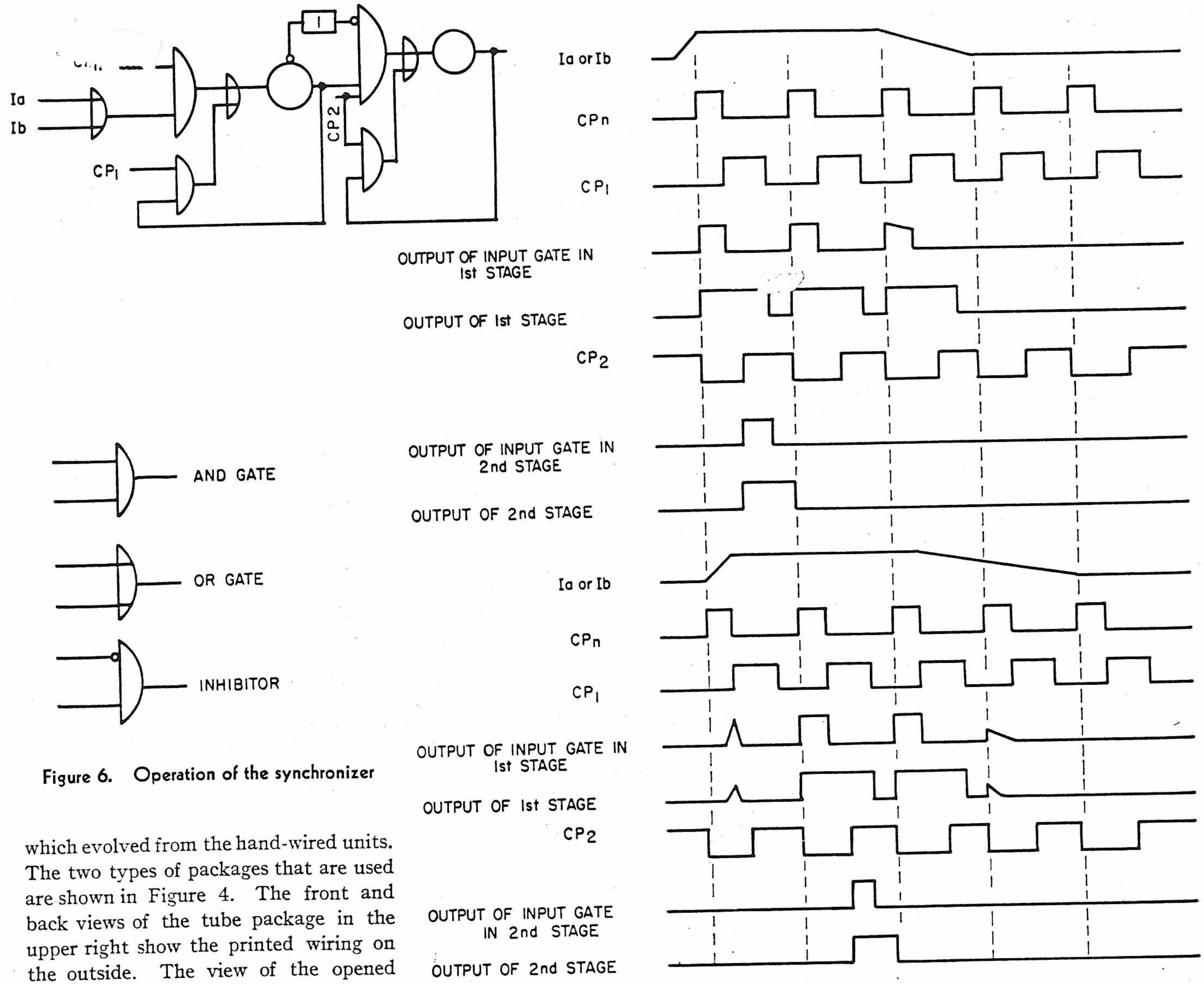


Figure 6. Operation of the synchronizer

which evolved from the hand-wired units. The two types of packages that are used are shown in Figure 4. The front and back views of the tube package in the upper right show the printed wiring on the outside. The view of the opened package below them shows the components inside. The front and back views of the delay line package, which includes the terminations for the lines, are shown in the upper left, and again the opened package is shown below.

The make-up of a SEAC word has already been explained in S. Greenwald's paper. As the word comes from the computer, the space and sign characters are differentiated from other characters only by their position in the word and, to a certain extent, by the information they contain. This means that counting of characters is necessary. This is done in the printer rather than in the outscriber. A Flexowriter punch is the terminal equipment on the outscriber. The typewriter used for printing from the paper tape is a Flexowriter. Flexowriter equipment was used mainly because, although promising for future computer work, it had had very little operating experience. Using it in the outscriber was one way of getting some of this experience.

These are the basic parts that are necessary in the outscriber as planned:

1. Wire drive.
2. Amplifier.
3. Some method of distinguishing a one from a zero.
4. Synchronizer: A device which can take a long slow pulse and produce one and only one pulse synchronized with a clock pulse.
5. Counter: To determine when enough pulses have been received to make a character.
6. Register: To store information contained in a character as the count progresses.
7. Buffer register: To store information for one character during punching while new information comes in.

The block diagram in Figure 5 shows how these parts fit together in the SEAC outscriber.

The wire drive has already been described by J. L. Pike. The pulse packing and wire speed are such that the punch is driven at about 12 characters per second. In both the inscriber and the outscriber, the pulse packing on the wire is very conservative. The wire drive is controlled by both manual switches and the error-checking circuit. The high-speed forward and reverse positions, as well as the low-speed reverse, are used for manual positioning of the wire. The low-speed forward is used for transcribing information only.

A high-gain low-frequency 2-channel amplifier is used. It must have high gain since the wire is moving only about 1 inch per second, and the signal induced in the head therefore is only about 200 microvolts. The 2-channel amplifier is needed to tell whether the signal on the wire is a one or zero. Pulses of opposite polarity are fed into the two channels of the amplifier by a center-tapped transformer. For each pulse on the wire there is a positive pulse in each channel. If the pulse in channel *B* follows the pulse in channel *A*, the pulse on the wire is a one. The method used is very similar to that used in SEAC. The low-pass amplifier has a cut-off of about 500 cycles. This is

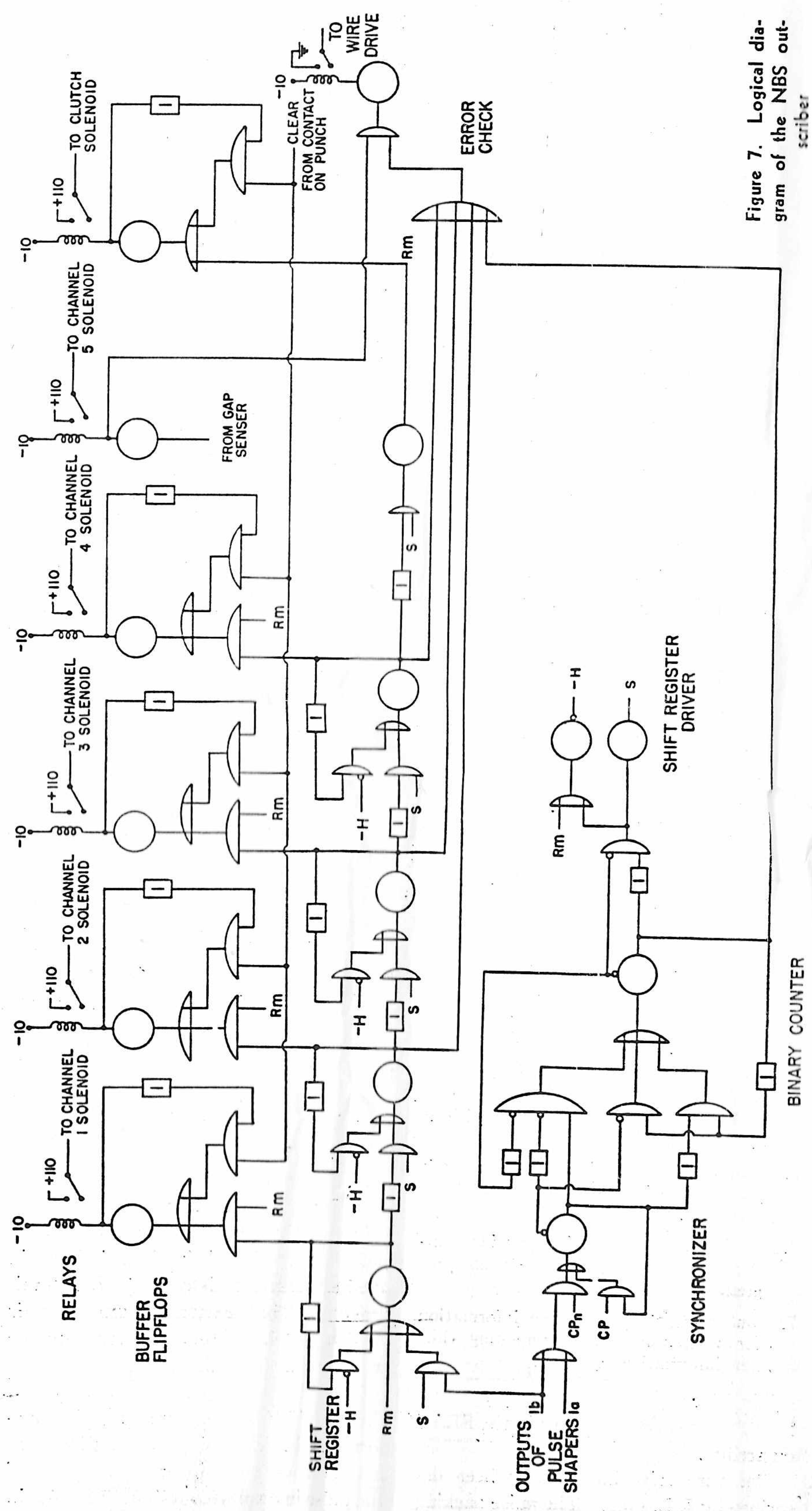


Figure 7. Logical diagram of the NBS outscriber

adequate for passing the signal and is desirable to prevent stray noise from being picked up.

The eventual use of the information from the amplifier is to drive gates in the part of the outscriber that is built from SEAC-type circuitry. Each gate load is about 10 milliamperes, which cannot be supplied by the high-impedance output of the amplifier. This current can be supplied by a tube and transformer as used in the computer-type circuitry. However, a signal applied to a pulse transformer must have a sharp rise, much sharper than that coming from the amplifier. This requires the use of pulse shapers in the outscriber, one for each channel of the amplifier. These consist of a Schmitt trigger circuit, which produces a square pulse for each positive pulse from the amplifier, followed by a pulse amplifier with a step-down transformer. This combination produces a pulse capable of driving several gates.

The circuitry from here on is the SEAC-type, which means that all signals have to be synchronized with the 1-megacycle clock. The output of the pulse shaper is a long pulse (2 to 5 microseconds) in comparison with the clock pulse (0.5 microsecond), and arrives completely asynchronously with the clock. The function of the synchronizer is to start with this pulse and produce a single half-microsecond pulse synchronized with the clock. There is a pulse out of the synchronizer for each pulse from the two pulse shapers, or two for each pulse on the wire. The synchronizer feeds these to the binary counter, which is a dynamic flip-flop, and produces one pulse for each two received, or one for each pulse on the wire. However, the pulse is produced at the time of the second pulse from the synchronizer, so that examination of the channel *B* output at this time will give the information as to whether the pulse on the wire was a one or zero.

The various ways of counting, such as a series of binary counters, a ring counter, and shift register, were considered and the amount of equipment required for the counter and register determined for each. Since the shift register both counts and stores information, it required the least equipment. The shift register is a series of dynamic flip-flops and works as follows: A marker is set in the first stage of the shift register, all others being cleared. Whenever a pulse is received from the binary counter, the marker is shifted to the next stage, and the first stage is reset if the pulse on the wire is a one, but not if it is a zero. When the next pulse is received from the binary counter, the marker is

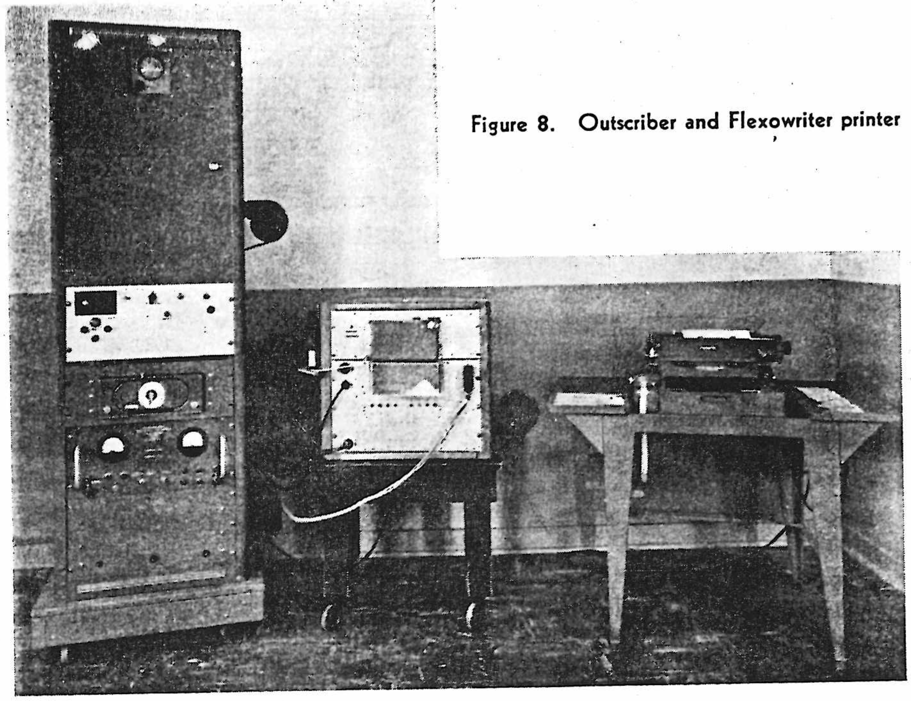


Figure 8. Outscriber and Flexowriter printer

shifted down another stage, the information is shifted to the second stage, and the first stage again reset or not, according to whether the pulse on the wire is a one or zero. This continues until the marker reaches the final stage, when the information in the other stages is dumped into the buffer flip-flops, the shift register cleared, and the marker reset.

The buffer flip-flops are also dynamic flip-flops, one for each stage of the shift register, which are set when the marker reaches the last stage of the shift register if the corresponding shift register stage is set at that time. The last buffer flip-flop is set each time, since it contains the information that enough pulses have been received for a character and that it is therefore time to punch. They are reset by a signal from the punch which indicates that the punching cycle has started and the information being stored is no longer needed.

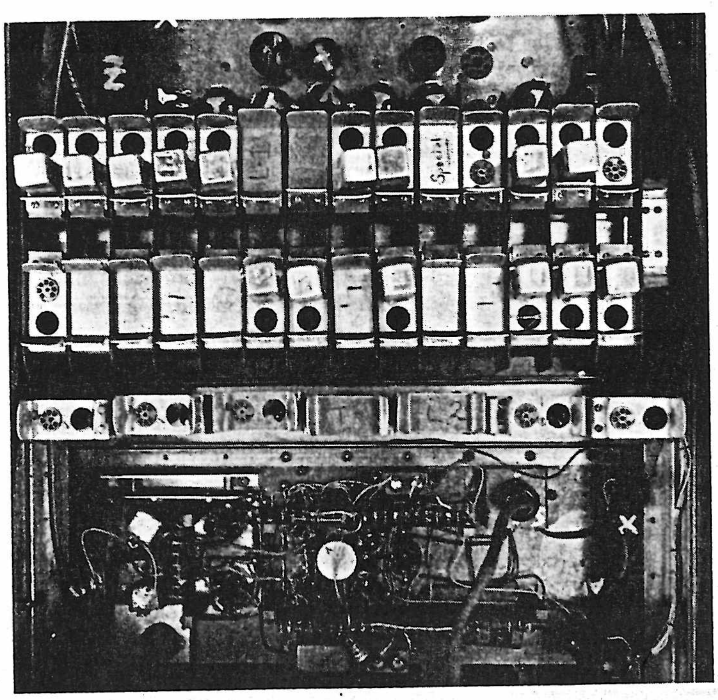
A method of driving a relay directly from the output of a dynamic flip-flop was worked out which, equipmentwise, made relays seem the best way of driving the solenoids in the punch. These solenoids require a current of approximately 0.25 ampere to operate. The energizing of the relays begins as soon as the buffer flip-flops are set.

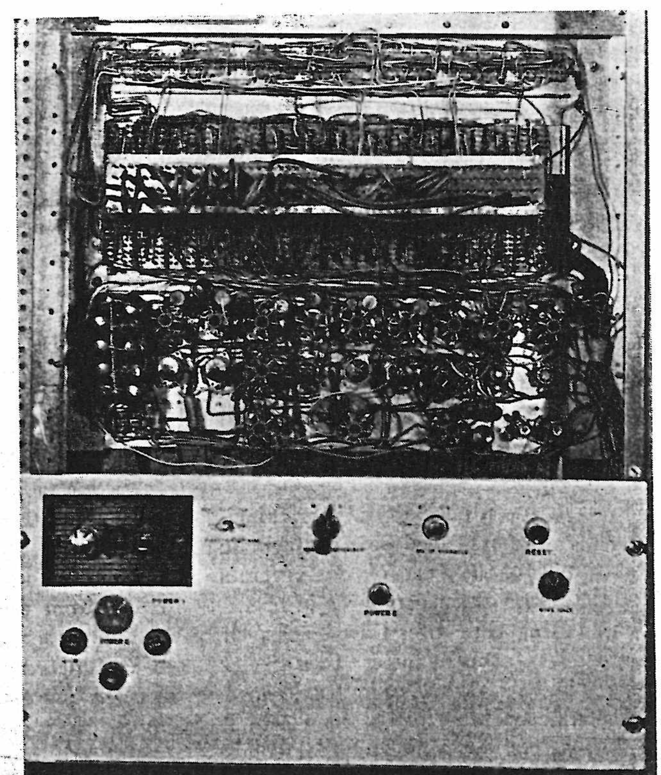
Contacts on the relays provide the power necessary to energize solenoids on the punch, which in turn set up interposers when channels are to be punched. The relay on the last buffer flip-flop (which gives the signal to punch) energizes the clutch solenoid which causes the motor shaft and the punch-operating shaft to be engaged, and starts the punch cycle. Once the operating shaft is engaged, the clutch solenoid armature can be released. Similarly, a cam causes a bail to lock the interposers in place so they cannot be changed during the punching operation and the solenoids which set the interposers can then be de-energized. At approximately the same time, a contact sends a signal to the buffer flip-flops, resetting them.

During the gap, if there has been no error, the first stage of the shift register should contain the marker and the other shift register stages, and the binary counter should contain nothing. If any of these stages except the first shift register stage are on, the error-checking circuit halts the wire and the wire-halt indicator is lit. The chance of an error getting through is very slight, as there would have

Figure 9 (below). View of the outscriber showing use of packages

Figure 10 (right). Wiring and switch panel of the outscriber





to be eight (or a multiple of eight) pulses gained or lost before the error would not be caught.

In case of an error, the operator can reverse the wire through the block in which the error was sensed by using the low-speed reverse position and trying again.

In 4-channel operation, the gap senser is also used to provide a fifth channel punch at the beginning of each block. This is used only as an aid to the operator to assist him in locating information visually on the punched tape.

One part which was rather blithely passed over, and which will now be described further, is the synchronizer. Figure 6 shows the logical diagram of this part as well as some idealized pulses. An AND gate or coincidence gate gives output when there are signals on all inputs. An OR gate gives output when any input has a signal on it. There is no output from an AND gate when an inhibitor input has a negative signal. The basic idea of the synchronizer is to use a narrow clock pulse to sample the signal coming in. If enough of a pulse is produced at the output of the transformer for the regeneration gate to catch and hold the output up as long as CP_1 lasts, a regular pulse is produced. If it does not, only a spike will be produced. However, the input pulse is long enough so that a full pulse will be produced at the next narrow clock pulse time. The second stage examines the output of the first stage. If only a spike comes through, it will be gone before CP_2 is up. The first regular pulse gets through the input gate and is lengthened by the regeneration gate. The length of Ia and Ib is such that there will always be at least two full pulses from the first stage. However, only one gets through the second stage because the negative of each pulse arrives 1 microsecond later to inhibit the next one, allowing only the first one to get through. This also means that a weak pulse toward the end causes no concern, since there is always a stronger pulse to inhibit it. The top group of signals shows a case where the first pulse that gets through the input gate is a full CP_N, and produces a normal pulse. The bottom group shows the other case where the first pulse is a spike and does not produce a normal pulse. The next pulse then produces it.

Figure 7 shows the logical description of the main part of the outscriber with the parts that are used in 4-channel operation. The logical parts that comprise the various blocks previously described are labeled. It will be noticed that the second stage of the synchronizer is combined with the binary counter. Attention is directed on the logical diagram to the method of recognizing a one on the wire. The binary counter is set by the first pulse from the pulse shapers. In case of a one, the first pulse is on Ia. The pulse on Ib turns it off. Between times, it produces a train of regular half-microsecond pulses. The gate which generates S is continually inhibited as long as this train lasts. However, after the train, the 1-microsecond delay line lets one pulse get through, producing S. Ib is still on at this time and the coincidence of Ib and S in the first stage of the shift register indicates a one.

The outscriber has been in operation for about a year and is usually in operation at least 16 hours a day. Figure 8 shows the outscriber and the Flexowriter printer. The unit on the left contains everything but the punch and some of the power supplies. Figure 9 shows the package part of the outscriber and Figure 10 shows the wiring side of the packages. The over-all performance is much neater than the wiring. The switch panel is in the lower part of the picture. The switch with the knob missing is the 4-to-6-channel switch which is never changed, since we have operated only with four channels up to this time.

The punched tape produced by the outscriber is fed into the printer where the proper characters, including sign and space, are interpreted. The number of columns up to four can be selected by a switch. The method of determining when a character is to be interpreted as sign or space is to use a contact on the carriage to sense the position of the sign. The space or carriage return always follows the sign.

The paper tape can also be used to punch cards. This operation merely makes square holes out of round ones. Two different units are used. The first one is a card punch ordinarily used for manual punching from a keyboard. A Flexowriter reader and a system of relays for code conversion were added. The other tape-to-card unit required only very minor alterations for use with SEAC. The first one was modified only because this commercial equipment was not available at the time.

Operational Experience with SEAC

ERNEST F. AINSWORTH

THE input-output to SEAC is principally accomplished with magnetic wire, and to the best of the author's knowledge no other computer in operation at this time uses this means. Of course, it is much faster than Teletype tape; it takes 17 minutes to load the high-speed memory from Teletype and this can be done in 10 seconds with the wire cartridge. But it also has many other factors in its favor when compared to other fast methods.

It is extremely convenient to carry to and from the machine. At present The Laboratory has 250 of these cartridges and each operator has several to contain his codes and results.

A cartridge can contain a fairly large amount of information, about 14,000 words. This is enough to load the high-speed memory many times and is the equivalent of over 7 hours of Teletype tape reading. Many programs may be put on the same cartridge, so the position indicator on the face of the cartridge makes it easy for the operator to select a given program. One other device which has been found to be useful is the loud speaker connected to the amplifier. This enables the operator to detect the location of the information exactly and also seems to give him a sense of satisfaction when he is able to hear something going on.

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The wire units are comparatively inexpensive. They consist of commercially available parts with some modification.

This system has been in operation about a year and a half and we are fairly well pleased with its performance. No statistics have been recorded on the failure rate of these units, but it is low enough so that very little thought is given to them, and operators are mildly annoyed when they fail to work the first time. Since there is no checking of input-output in SEAC a summing technique is used to detect read-in errors. After the machine has taken in information, it is instructed to sum up all the information just read in and print out the sum. If the sum is correct, it is allowed to continue; if not, the information is read in again.

One of the objectionable features of the equipment as it is presently used is the long start-stop time. It takes over one second for the wire to attain full speed. When first installed, the start was much faster but this resulted in many broken wires. It did not appear possible to overcome this difficulty without considerable modification of the original equipment, so slower operation was employed. It was not the jerk of sudden starting that broke the wire, but the operation of the clutches threw out a slack loop when the wire stopped. When started again the wire developed a kink and broke. Plated wire breaks very easily when kinked.

Wire breakage is one of the troubles with a system of this kind. Sometimes it is due to operator error, sometimes to mechanical failure. Often it is impossible to say which. At any rate, it does not happen very often and we do not consider it a serious objection. In a 6-month period, about 10 to 20 wires break, out of the 250 cartridges in use. When the wire does break, the cartridge can be rewound with new wire or the old wire can be spliced and used, if the spliced area is avoided.

Experience with the type of tape units described by J. L. Pike shows that they possess many good qualities. One thing they definitely prove is that it is certainly possible to get fast and reliable start-stop times without complicated and high-power servo systems. These tape drives are also comparatively inexpensive and easy to construct. They require very little maintenance. The part that wears out most quickly is the ball bearing in the jam roller. They are held in place by one bolt and usually last 2 to 3 months. Sometimes the tire on the jam roller wears and develops flat spots. Since the use of nylon was introduced for these tires, it has been necessary to resurface one tire in about the last six months.

At present, the tapes are being run at 60 inches per second and printing at 110 pulses per inch. The tapes run quite well at 10 feet per second, but at present the computer cannot receive pulses as fast as this would present them. The amount of information that can be put on a tape depends on the manner in which it is recorded. When it is desired that the tape be able to stop between batches of information on it, enough blank space must be left for it to be able to do so. This space is left on in the printing operation by delaying the printing until the tape has had time to move sufficiently. SEAC can print or read, at most, eight words per instruction. If the program calls for more information than eight words at a time, there is no point in leaving this blank space every eight words since the tape is to keep on running. The computer is constructed so that the programmer may state in the instruction whether he wants this space left or not. We call printing without these spaces 'compressed' printing. Using compressed printing, a 600-foot tape takes 12,000 words; with uncompressed printing, it takes 8,000 words. The entire high-speed memory can be read in or printed out in less than five seconds.

Since SEAC does not check its input-output, it is necessary to put checks in the program. One way to do this is to reverse over the information immediately after printing on the tape, read it back in, and check with what is still in the memory. A shorter way is to have the last word printed be the sum of the previous words. Then each time the information is read in, it can be summed and checked. If the sum shows an error, the computer can back up and try it again with a very small loss of time. This will usually be successful as almost all of our errors are reading errors caused by missing a digit. We have had reported runs of five and six hours with no errors at all. This is with the use of commercially available tape and home-recorder quality heads. There has been a negligible amount of trouble due to flaws on the tape. This we believe is because a

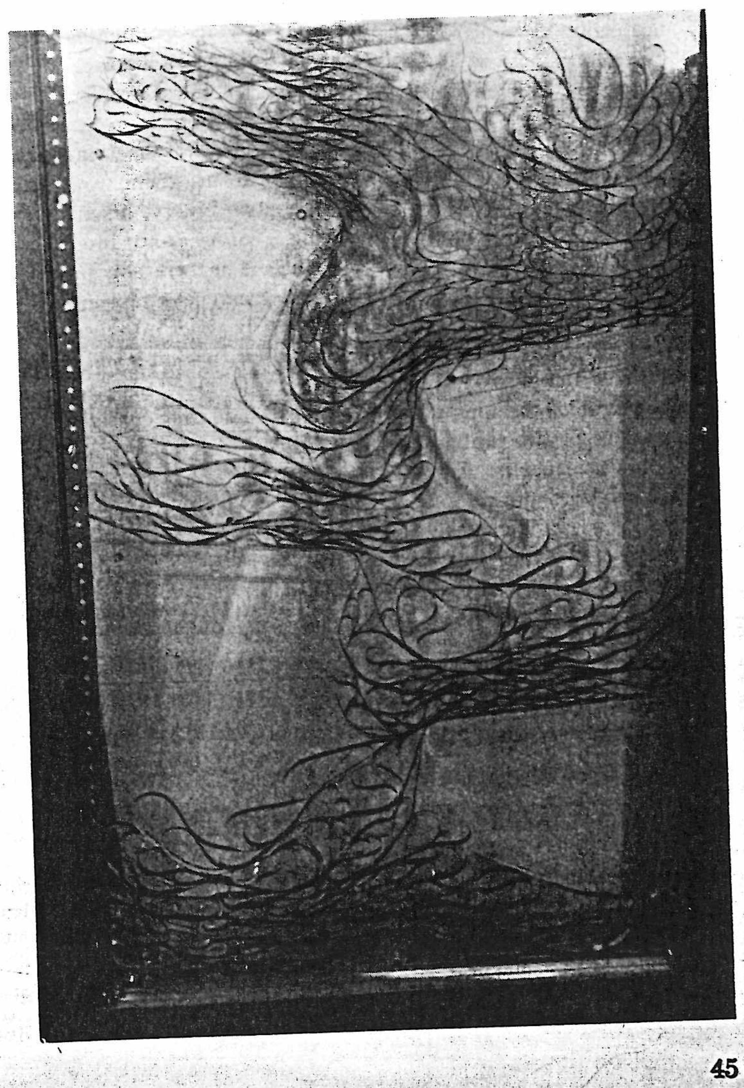

Figure 1. Tape drive unit showing tape supporting projection

1- to 8-inch channel width is used and because of our use of the tape scraping process previously described by J. L. Pike. After the tapes have been scraped, we print them from one end to another and examine them for any bad spots, but we reject very few.

When this type of tape unit was first used, there was trouble with the tape becoming electrostatically charged and sticking to the side of the tank. Radioactive material was inserted in the tank to help the charge leak off. This was an improvement, but was not very effective at speeds much over 3 feet per second. A tape with a conductive coating was tried and this eliminated the trouble completely. In fact, it eliminated it so completely that it now contributes to our present large difficulty involving creases in the tape.

The tape falls to the bottom of the tank so readily that the tape on the bottom is creased by the weight of that above it. These creases cause the tape to be held away from the head, resulting in smaller than normal pulses.

This is by far the worst trouble with the tape units. It has been found to be related to how much tape is in the tank and how long it is left there. At present we are putting only 600 feet of tape in a unit and we find we must replace it in 1 to 2 weeks. Neither of these requirements prevents profitable operation, but it is hoped to improve the situation. The problem is being attacked from two directions: (1) trying to keep the tape from being creased, and (2) improving the ability of the units to read through a crease.

To prevent creases, one of the methods tried was to tilt the unit to about 40 degrees from the horizontal, so that part of the weight of the tape was supported by the sides of the tank. This helped, but not very much. Another method being tried is to put projections in the tank as shown in Figure 1. As may be seen, part of the tape rests on each support and no part of the tape has to bear the weight of very much tape above it. This helps quite a bit. It is found that tapes can be left in this unit for 3 or 4 weeks as compared to 1 or 2 weeks in the other units. We are also looking for tapes with different types of plastic bases, hoping that one may be found that is more crease-resistant.

To the problem of making the tape unit put up with more severe creases the approach has been to improve the way in which the tape is held against the head, putting more pressure on the tape right at the gap, where it will do the most good. Results on the test bench look quite promising, but it has not yet been put into operation on the computer.

Perhaps a clearer picture of the operational characteristics of the wire and tape units will be obtained from a description of how they are used in the solution of a particular problem. The problem chosen as typical is the finding of a minimum solution of a 50 by 72 matrix, subject to certain conditions. It is solved by the simplex technique, and the same code is used for a matrix of any size up to 50 by 72.

The first phase is a preparation phase. The instructions are read into the machine from wire in about 8 seconds. A cartridge containing the data for the problem is now placed in the wire unit. In a typical problem it contains about 500 nonzero elements. The computer now reads in the data 8 words at a time, transforms them from binary coded decimal to binary, arranges the data in suitable order, and inserts the zero elements. They are now printed out on one of the magnetic tape units and checked by reading back into the computer and comparing with what is still in the memory. Around 4,000 words are printed on the tape. The time consumed by this phase is:

Wire data read in	2 minutes
Computation	4 minutes
Print and check tape	3 minutes
	9 minutes

The acutal solution of the problem is done in the second phase. This consists of processing the data a number of times until a solution is reached. Each data processing performs the following operations: 56 words of data are read in from one tape unit, are operated one by the machine, and then printed out on a second tape unit. The output data from this processing become the input data for the next one. One of these processing cycles takes the following time:

Tape running	2.5 minutes
Computing	2.0 minutes
Teletype printing	0.25 minute
	4.75 minutes

The number of times it is necessary to go through the processing cycle to get a solution depends on the problem. The simplex method of solving approaches the answer progressively. The number of cycles required cannot be determined beforehand.

Assuming that the cycle is gone through 72 times, this phase of the problem takes 72 by 4.75/60, or 5.75 hours. About 52 per cent of the time is tape-running time.

The final phase of the problem is the checking and presentation. The answers are substituted back into each of the 50 original equations to see if they satisfy. Results are changed from binary to binary-coded decimal and printed out on Teletype:

Tape	1 minute
Wire	3 minutes
Computation	3 minutes
Teletype	7 minutes
	14 minutes

There have been quite a few problems of the type just described actually run on SEAC.

It is the belief of the author that the experience with SEAC described in this paper shows that it is possible to construct from commercially available components some comparatively inexpensive input-output devices which are of somewhat modest performance but reliable and certainly useful for computer applications.

Discussion

W. H. MacWilliams (Bell Telephone Company): I have heard speakers referring to a Dyseac. I assume that this is an automatic computer. Can you tell me what else does it mean?

S. Greenwald (National Bureau of Standards): The reason for the particular term has to do with the sponsoring agencies and the purpose of the computer. It is a new computer that is coming along well. It is built somewhat along the logical lines of SEAC, but uses the printed wiring described in Miss Haueter's paper. It will be a good deal more powerful than SEAC, in that it will permit input, output, and computing functions to go on simultaneously. It will also be a good deal easier to maintain, we hope, because of the plug-in features.

H. F. May (Teleregister Corporation): What is the technique used to eliminate static charges on the lucite plate in the tape storage unit?

J. L. Pike (National Bureau of Standards): They are coated with a product, known as Photosweep, which can be purchased in photo equipment houses. The composition of it I know nothing about but, when sprayed on lucite, it eliminates completely static charges and seems to wear forever. We have had no trouble with it.

Mr. MacWilliams: What work have you done on multichannel recording?

Mr. Greenwald: For some time, we have been experimenting with multichannel recording. For this purpose, we have used a Raytheon-type mechanism similar to the one described by Mr. Snyder. In this par-

ticular equipment, we use five channels of information, and one sync channel. We have not considered it a high-priority job, because we felt it was more important to get some of the other equipment working, and working well. However, we do intend to incorporate one of the multichannel units in SEAC in the very near future. We hope it will work out.

C. T. Schaedel, Jr. (Consolidated Vultee, Fort Worth Division): Using the miniaturized printed circuit technique for your components and packages, have you ever had trouble with the component failing during actual computer operations? You described part of your developed circuit technique for your packages. Do you have trouble with reliability of the components for using the printed circuit?

Miss Haueter: I mentioned the fact that the printed circuit package would be used in Dyseac. We are not using it in any of the equipment we now have. The outscriber shown was a hand-wired unit. The situation should not change in printed circuits any more than in hand-wired circuits. We would expect the same failure that is obtained in anything that uses dials, tubes, and transformers.

Mr. Schaedel: Did I understand you to say that you did not remember an error ever having occurred? That would indicate you have had no component failures during the computer operation.

Miss Haueter: I stated that I know of no error that got through our error-checking circuit.

Mr. MacWilliams: A nice distinction.

O. Whitby (Stanford Research Institute): I wonder whether any of the speakers can tell me whether they can distinguish between misreads from the tape due to dust and those due to kinks?

Mr. Ainsworth: We have no way, at the moment, of telling if they are dust or not. When we first hooked up the equipment, we looked for kinks when we had errors; we almost always found them there. I do not think dust would cause as much trouble with the 1/8-inch channel width that we use on the present tape system.

R. C. Boe (Cook Electric Company): Will Miss Haueter elaborate on this method of synchronization?

Miss Haueter: Our basic repetition rate is 1 megacycle. We use the dynamic flip-flops, which means when a flip-flop is turned on, it continues to put out pulses at a 1-megacycle rate, until something turns it off. Therefore, there is no conflict. It continues to put out pulses until something occurs later on, even though what has happened is at a very low rate. The actual synchronizing process which I referred to consists of generating a single 0.5-microsecond pulse from a longer pulse which occurs asynchronously with the clock. This is a somewhat more difficult problem which I had hoped to discuss, but did not have time.

The Uniservo—Tape Reader and Recorder

H. F. WELSH H. LUKOFF

A PRACTICABLE method of obtaining adequate input-output speeds for digital computing devices is the high-speed tape recording method, but the designing of a good tape system has been, to say the least, extremely difficult. In this paper, the history of the development of Uniservo, the Univac tape transport device, will be briefly sketched.

The need for higher speed input and output devices became apparent as soon as the idea of electronic computing was projected. Among the early objectors to computers, the more farsighted pointed out that, even if a machine could be made, its use would be severely limited by inability to converse with it at appropriate speed. It was realized at the time that a great deal of development work on input and output devices was necessary before a satisfactory commercial computer could be built.

It was fortunate that the first Univac contract was with the Bureau of the Census. The Census problem demands large quantities of conversation and therefore the computer, to be useful, had to have extremely high speed input and output equipment. The final specifications for the future Uniservo were decided upon with the Census problem in mind, yet without making the computer in any sense a single-purpose device.

The most important aim in speeding up input and output operations was to have them interrupt the computer as little as possible. With this established, certain decisions became immediately necessary.

First, it was decided that input and output operations should take place in two separate steps. For input, the preparation of tape takes place apart from the computer, in a Unityper* or card-to-tape converter. Reading of data from tape into the computer takes place at higher speed on a Uniservo. For output the computer records on tape by way of a Uniservo but the printing of the data takes place apart from the computer on a Uniprinter.*

The second decision was to tolerate no speed less than that obtainable with high-density mutichannel magnetic recording. Here was envisaged the Uniservo, a tape transport device recording parallel channels on magnetic tape. The following performance characteristics were predicted:

Speed..............120 inches per second

Pulse density..........100 pulses per inch

Instantaneous conversation rate..................12,000 decimal digits per second

The third decision was to make all input and output operations automatic, that is, to have all Uniservo operations initiated by programmed instructions in the computer memory. In view of the fact that the speed of reading and writing on tape is slow compared with the speed of electronic operations, it was decided to include separate control circuits for input-output operations. Consequently, the computer circuits do not have to be tied up all the time the Uniservo is in operation. In fact, there are only two functions which require the co-operation of the central computer control circuits:

1. Instructing a Uniservo to read or write.
2. Transferring from an input register to the memory or from the memory to an output register.

For the input instructions, the logical sequence is to read from tape and then transfer from the input register to the memory, but this would require the com-

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* Reg. U. S. Pat. Off.